Trenton, Missouri
Water Supply Study

Introduction

This analysis was made to assess the availability of Trenton's water supply. Trenton obtains their water supply from Thompson River. Thompson River stream gage at Trenton, drainage area 1670 square miles is located approximately one mile downstream of the pump intake. Analysis indicates insufficient instream supply to meet demand during an extended multi-year drought such as the 1950's

Discussion:

Two pumps, pump from Thompson River to the storage basins, each pump is rated at 3125 GPM. They use one at a time and keep the other in reserve. 3125 GPM is near treatment plant capacity of 4.5 MGD. 3125 GPM = 6.96 cfs.

Stream flow data was obtained from USGS water supply data. Mean daily discharges were used to analyze stream flow volumes and frequencies. Continuous records have been kept from 1928 through 2002.

There are two raw water storage basins. The south basin has a surface area if 13.5 acres with storage capacity of 75.3 acre feet (24.5 million gallon). The maximum depth is 20 feet. The north basin has a surface area of 34.9 acres with storage capacity of 430 acre-feet (140 million-gallon). The maximum depth is 17 feet. The operating procedure is to keep the basins as near full as possible. When using water at treatment plant capacity of 4.5 MGD the supply in the basins would be used up in 36 days with no additional inflow. Figure 9a shows that the maximum water usage of 2.055 MGD occurred in 1993. At this demand there would be 80 days of water stored in the basins.

Annual precipitation amounts for most of Missouri has been increasing during the last 50 years. This is shown in the state water plan. The study was recently made for the state by Steve Hu (former state climatologist at University of Missouri) to update climate data. **Figures 70.1.a and 70.1.b** illustrate the precipitation trend for two gages near the center of the Thompson River drainage area. One gage is at Princeton, Missouri and the other at Lamoni, Iowa. These stations trends, show 50 year precipitation increase of 23% at Princeton to 32% at Lamoni for years 1950 through 2000. **Figure 70.2** shows the effect of increased annual rainfall on runoff. The trend indicates an increase in total annual runoff from 7.5 watershed inches to 10 inches or approximately 33% from 1955 to year 2000. The drought of record was in the 1950's. Non-excedence probabilities for the 1%, 2% and 4% chance flows in figure 7 are compared to actual stream flow records in **figures 70.3.a through 70.3.d** for the drought of record (1954 through 1957). These monthly runoff volumes for 1954, 1955, 1956 and 1957 were obtained from USGS stream flow records. These figures show that mean monthly discharge in Thompson River falls below the 7 day Q10 low flow (9 cfs) for 3 months. These occur in January 1954 when discharge = 7.1 cfs, December 1955 discharge = 6.5 cfs and January 1956 discharge = 4.7 cfs.

Figure 70.3.a compares 1954 mean monthly flow to monthly probability shown in figure 7.
Figure 70.3.b compares 1955 mean monthly flow to monthly probability shown in figure 7.
Figure 70.3.c compares 1956 mean monthly flow to monthly probability shown in figure 7.
Figure 70.3.d compares 1957 mean monthly flow to monthly probability shown in figure 7.

Base flow separation was made using the USGS computer program, HYSEP. This analysis was made to estimate sustained flow, in order to establish availability of continuous stream flow. **Figure 70.4.a** is the base flow index and is the ratio of base flow to total stream flow. This chart shows the yearly fluctuation in base flow indexes and indicates the trend. The trend has increased from 26% of total annual runoff in 1955 to 38% in 2000. The increase in annual base flow volume is shown in **figure 70.4.b and 70.4.c**. Figure 4b illustrates the runoff in watershed inches. Figure 4c shows the same runoff in terms of cubic feet per second at the

intake. Annual base flow volume has doubled from 1.9 inches to 3.8 inches in the last 50 years.

To determine the rate of flow needed to meet in-stream flow requirements, the 7 day Q10 low flow was determined using the period of record, 1950 through 2000. **Figure 70.5** shows the results of the frequency analysis to be 9 cfs. For purposes of pumping from the river to fill the storage basins, discharge needed to exceed 9 cfs.

Mean seven-day annual low flows for 1928 through 1999 were calculated and are shown in **figure 70.6.**
The lowest 7-day discharge occurred in 1956 with a mean value of 2 cfs.

Monthly non-excedence probabilities for 1%, 2% and 4% chance of occurring were established from stream flow data for the years 1950 through 2000. **Figure 70.7** displays the 1% and 2% mean monthly low flow. The 4% chance indicates discharge to be more than 7day Q10 discharge for all months. For this report, all statistical determinations were made using the Log Pearson type III method as described in Water Resource Council bulletin 17B.

Deficits shown in the following displays are the volume shortages necessary to meet the 7-day Q-10 in-stream flow requirements. **Figure 70.8.a** shows non-excedence probability flows of the 1% chance of occurrence and indicates that half of the months, March through August exceed the 7-day Q-10 flow rate, The remaining months were below the 7-day Q-10 flow rate. **Figure 70.8.b** is the 2 percent chance low flows and indicates only three months are close to 7 day Q 10 discharge, and they would have enough carry over storage in the reservoirs to provide adequate water. **Figure 70.8.c** shows the 4% chance of occurrence is able to provide enough flow so that there would be no deficit. **Figures 70.8.d and 70.8.e** display the deficits in bar charts, one showing the deficit in acre-feet and the other in terms of cfs.

Water usage for the last seven years of record are:

1995	1.38 MGD
1996	1.62 MGD
1997	1.47 MGD
1998	1.51 MGD
1999	1.64 MGD
2000	1.84 MGD
2001	1.90 MGD

Figure 70.9.a shows that the long-term trend (1983 through 2001) daily water usage has increased from approximately 1.5 MGD in 1983 to 1.75 MGD in 2001. Resulting in a daily increase in demand of 17 %. Historical use from 1995 through 2001 increased from 1.38 MGD to 1.90MGD, and increase of 38%. **Figure 70.9.b** shows total annual usage in million gallons per year.

Additional comparisons for the 1950's drought were made using the mean 7-day low flow for examining a shorter duration. These comparisons are shown in **figures 70.10.a, 70.10.b, 70.10.c and 70.10.d**. These figures compare mean seven-day low flows to 7 day Q10 flow, and indicate short-term critical periods. In the 4 years period of 1954 through 1957 there were 12 months that had mean seven-day flows below 7 day Q10 discharge.
They were:
1954 – 3 months January (4 cfs), February (4 cfs), September (8 cfs).
1955 - 3 months September (6cfs), November (8 cfs), December (5 cfs).
1956 - 5 months January (4 cfs), February (5 cfs), April (4 cfs), May (3 cfs) and June (2cfs).
1957 - 1 month October (6 cfs).

Conclusions:

Mean monthly Thompson River discharges will be less than the 7-day 10-year frequency discharge of 9 cfs for the 1% chance or 1 year in 100 years low flows for six months of January,

February, and September through December. For the 2% chance or 1 year in 50 years, these same months were very close to the 7 day Q10 flow with January and December being slightly less and 4 months had flows approximately equal to the minimum 9 cfs.

During the 1950's there were no months that flow in Thompson River would not allow pumping at the rated pump capacity of 3125 gallon per minute (6.96 cfs) for at least some of the month. However there would be longer periods of time flows would be too low for pumping. This is indicated by the 7-day low mean discharge values for 1954, 1955, 1956 and 1957. Each year had mean 7-day duration flows below pump ratings.

Trenton's demand is increasing at a long-term rate of 0.013 MGD. The present system is meeting their needs. The treatment plant is able to treat 4.5 MGD and the current demand is less than 2 MGD. Between years 1928, when the stream gage on Thompson River was installed, to year 2001 there were five 30 day periods when pumping from the river to the reservoirs could not occur. These were all in 1956 or earlier. They are: July 1954, January 1940, December 1955 and January 1956, as well as May 1956. With the storage in the reservoirs, City demand could be met during the 30-day dry periods.

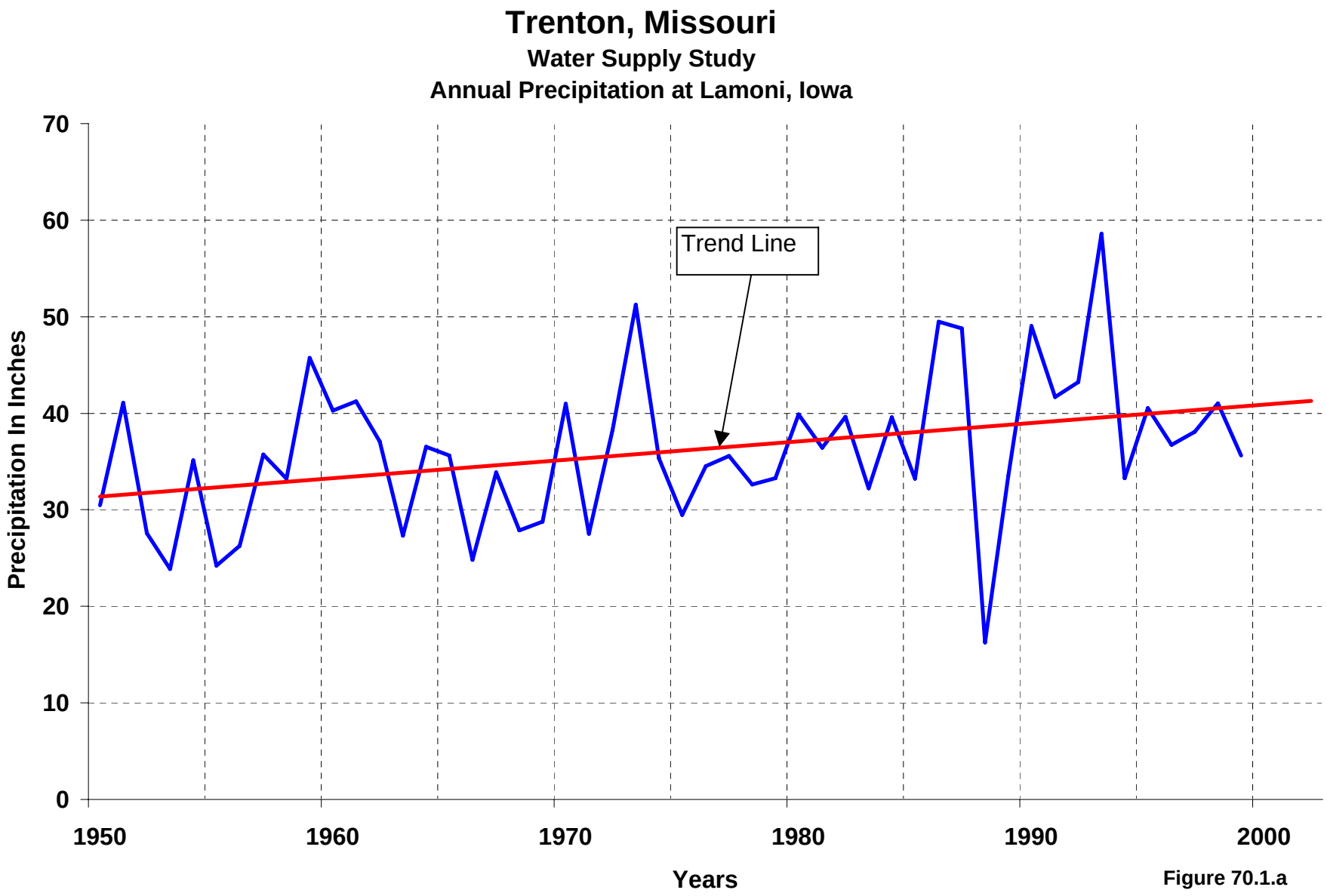

Trenton, Missouri
Water Supply Study
Annual Precipitation at Lamoni, Iowa
Trend Line
Precipitation In Inches
Years
0
10
20
30
40
50
60
70
1950
1960
1970
1980
1990
2000

Figure 70.1.a

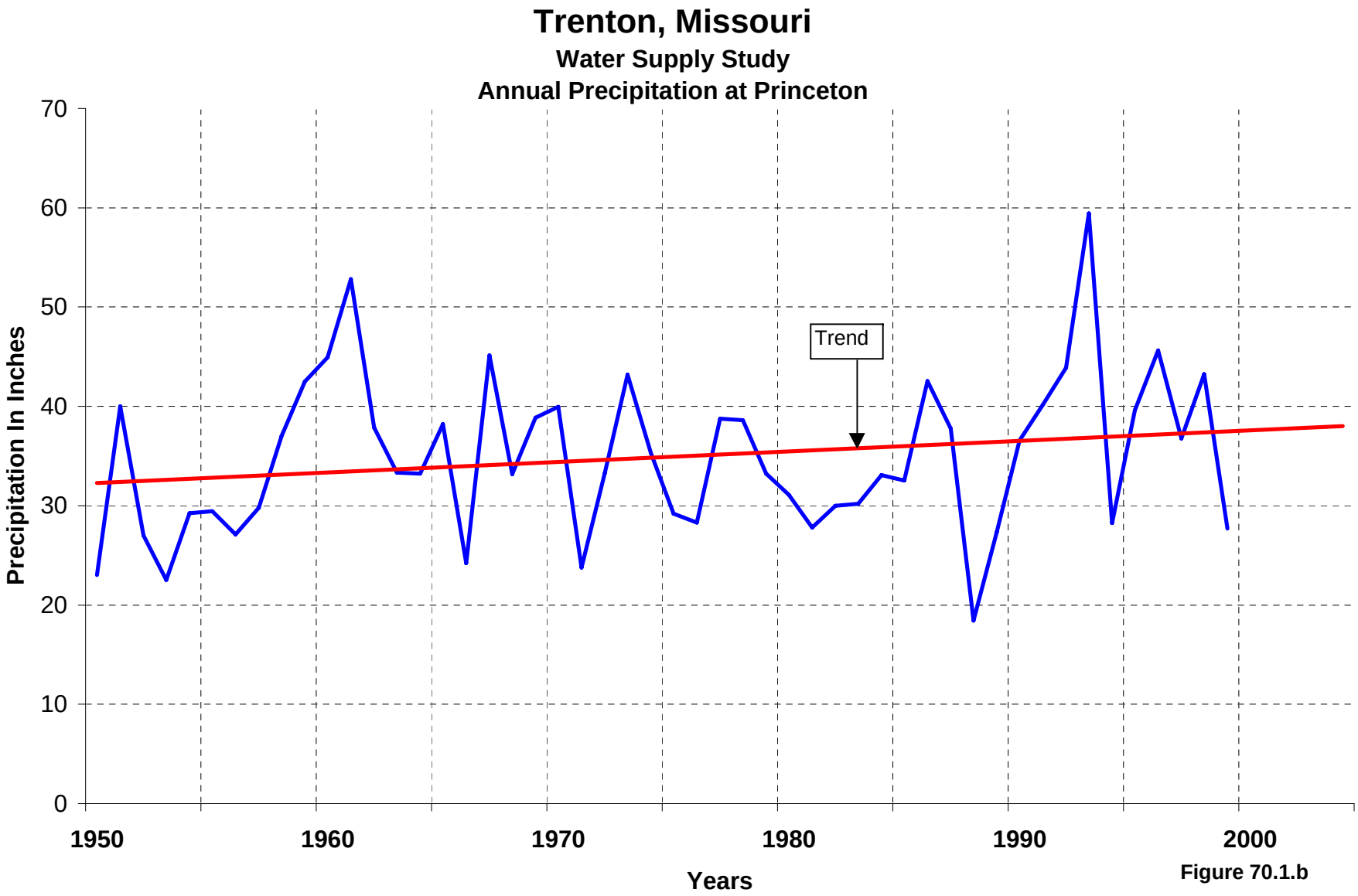

Trenton, Missouri
Water Supply Study
Annual Precipitation at Princeton
Precipitation In Inches
70
60
50
40
30
20
10
0
1950
1960
1970
1980
1990
2000
Years
Trend

Figure 70.1.b

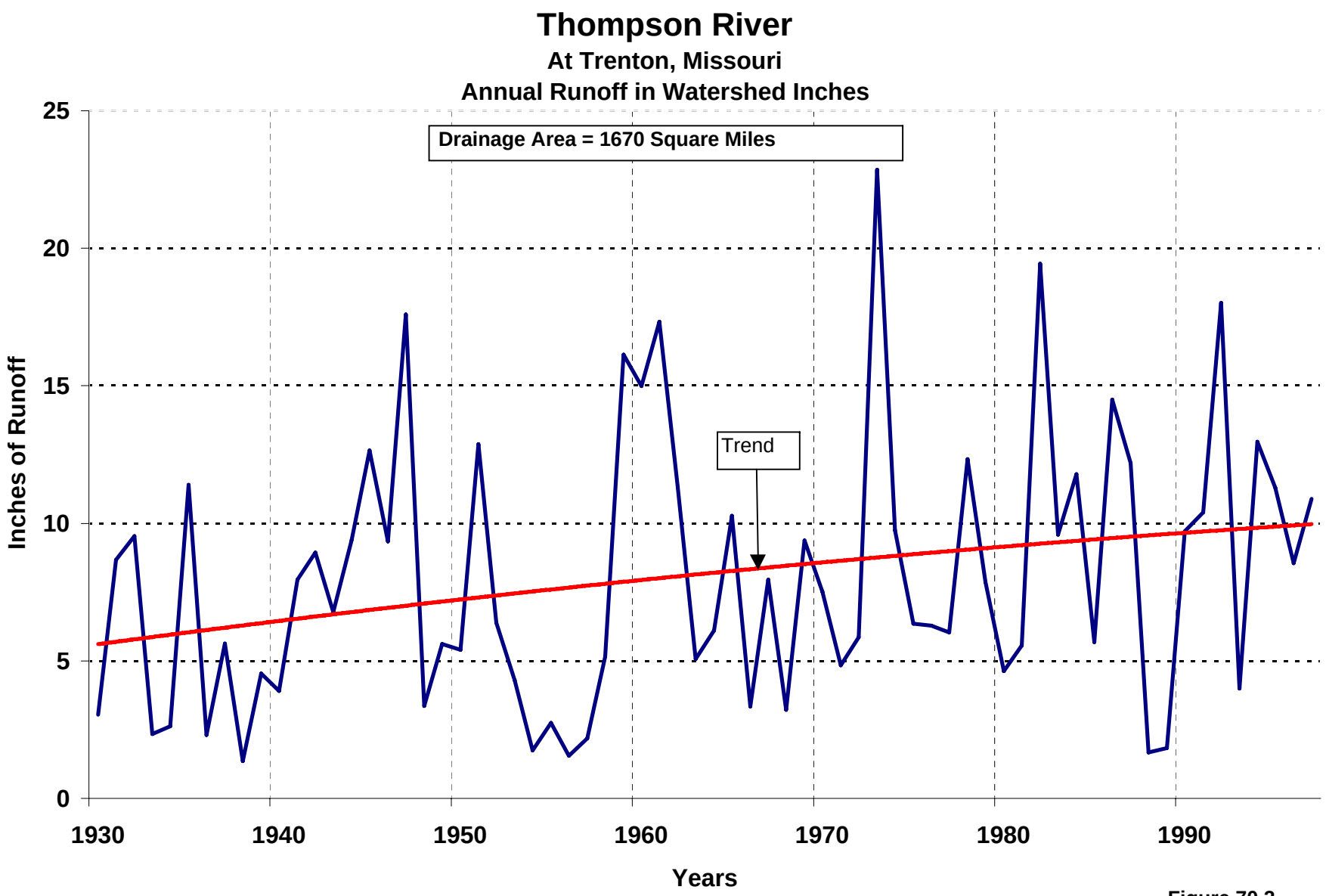

Thompson River
At Trenton, Missouri
Annual Runoff in Watershed Inches
Drainage Area = 1670 Square Miles
Trend
Inches of Runoff
25
20
15
10
5
0
1930
1940
1950
1960
1970
1980
1990
Years

Figure 70.2

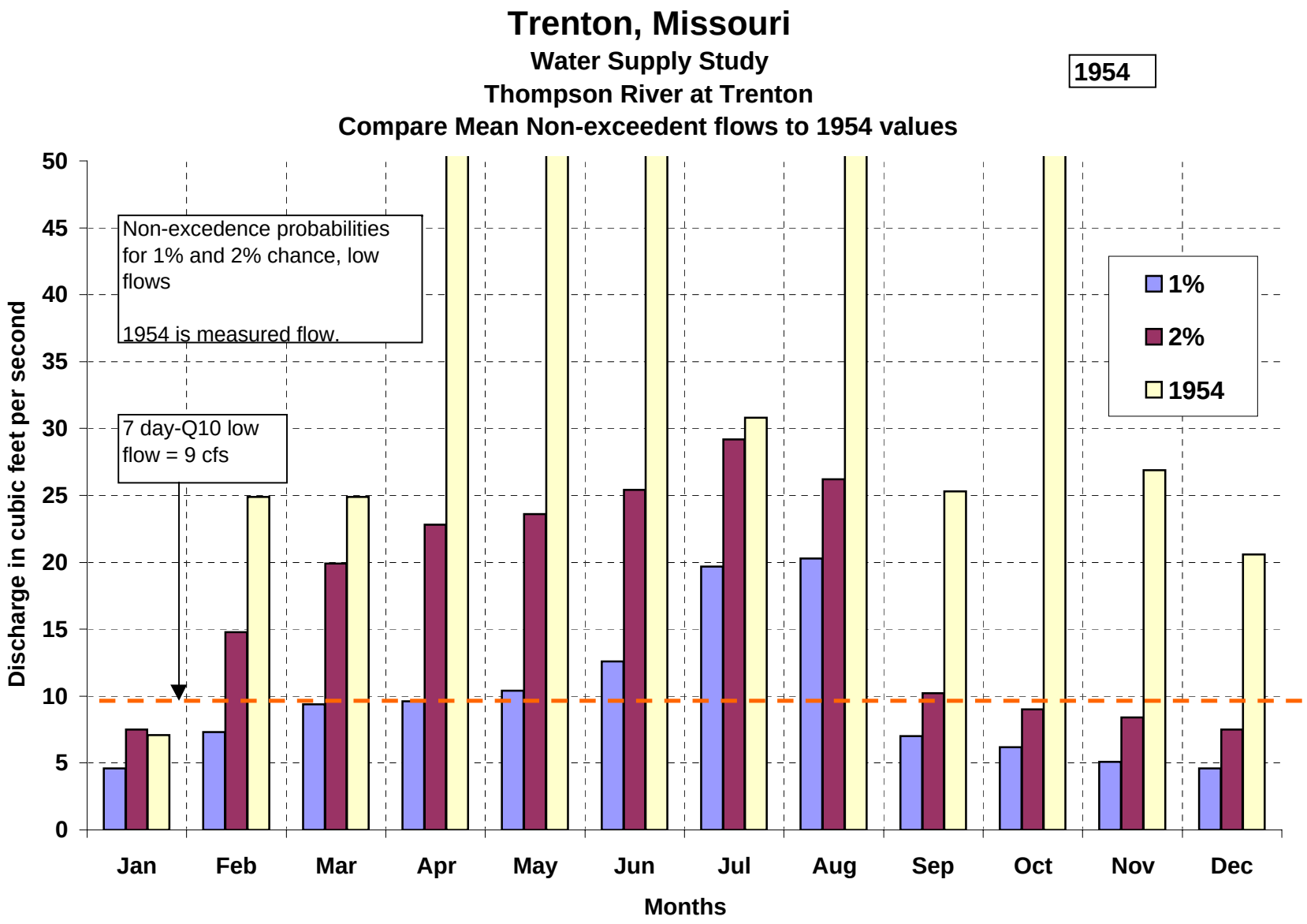

Trenton, Missouri
Water Supply Study
Thompson River at Trenton
Compare Mean Non-exceedent flows to 1954 values
1954
Non-excedence probabilities for 1% and 2% chance, low flows
1954 is measured flow.
7 day-Q10 low flow = 9 cfs
1%
2%
1954
Discharge in cubic feet per second
0
5
10
15
20
25
30
35
40
45
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 70.3.a

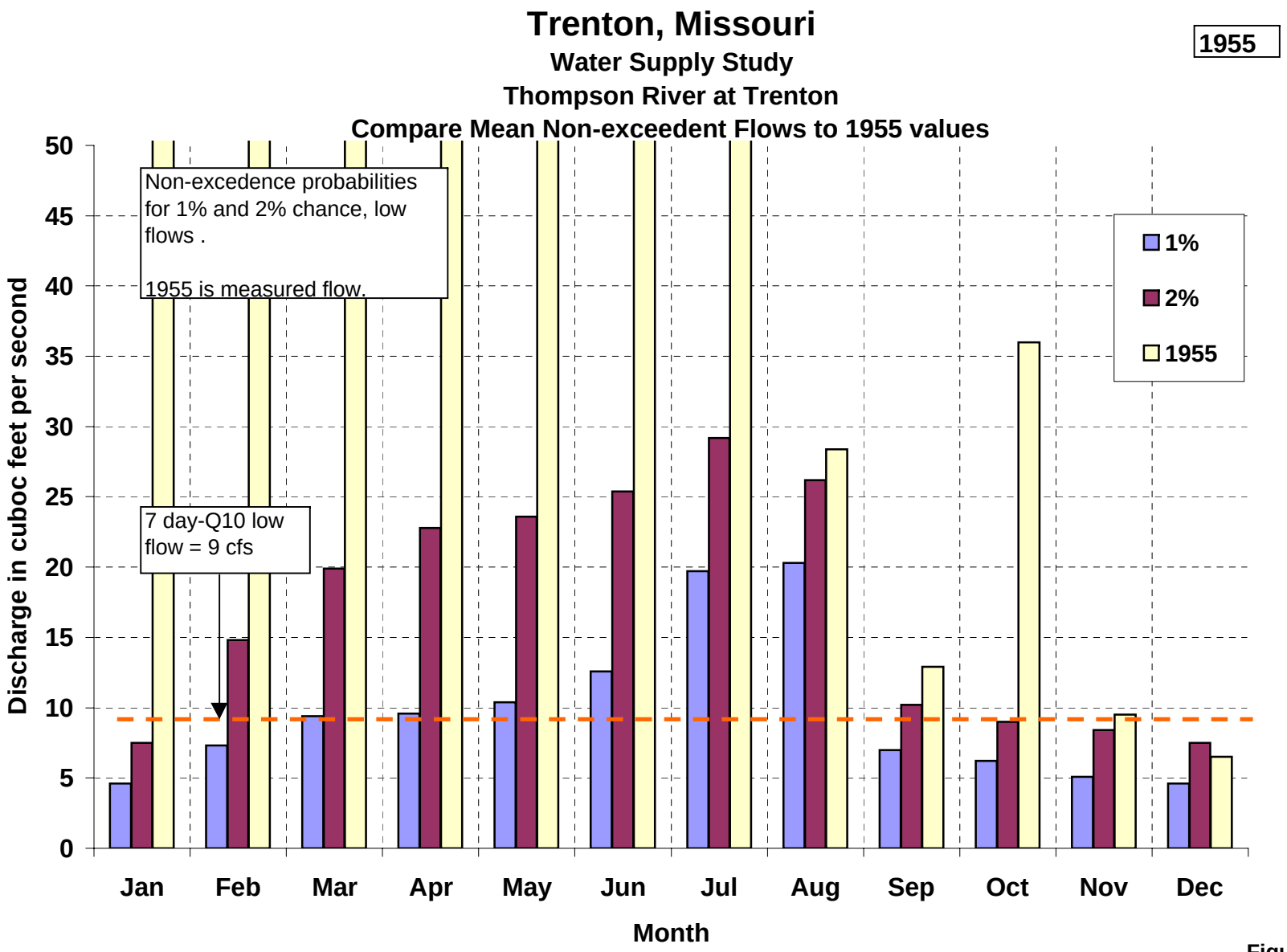

Trenton, Missouri
Water Supply Study
Thompson River at Trenton
Compare Mean Non-exceedent Flows to 1955 values
1955
Non-excedence probabilities for 1% and 2% chance, low flows .
1955 is measured flow.
7 day-Q10 low flow = 9 cfs
1%
2%
1955
Discharge in cuboc feet per second
0
5
10
15
20
25
30
35
40
45
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 70.3.b

Trenton, Missouri
Water supply Study
Thompson River at Trenton

1956

Compare Mean Monthly Non-exceedent Flows to 1956 values

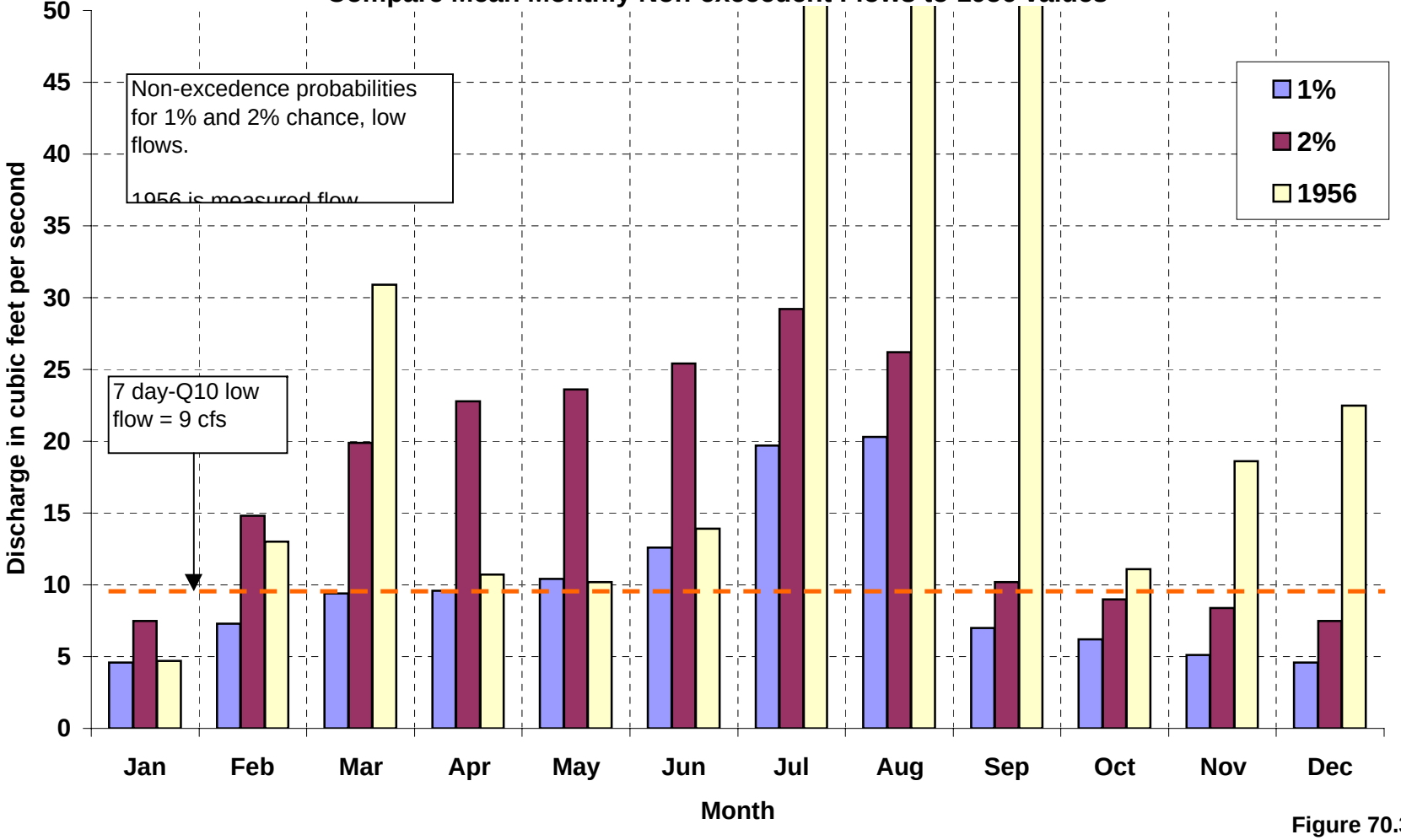


Figure 70.3.c

Trenton, Missouri

Water Supply Study

Thompson River at Trenton, Missouri

Compare Mean Monthly Non-exceedent Flows to 1957 values

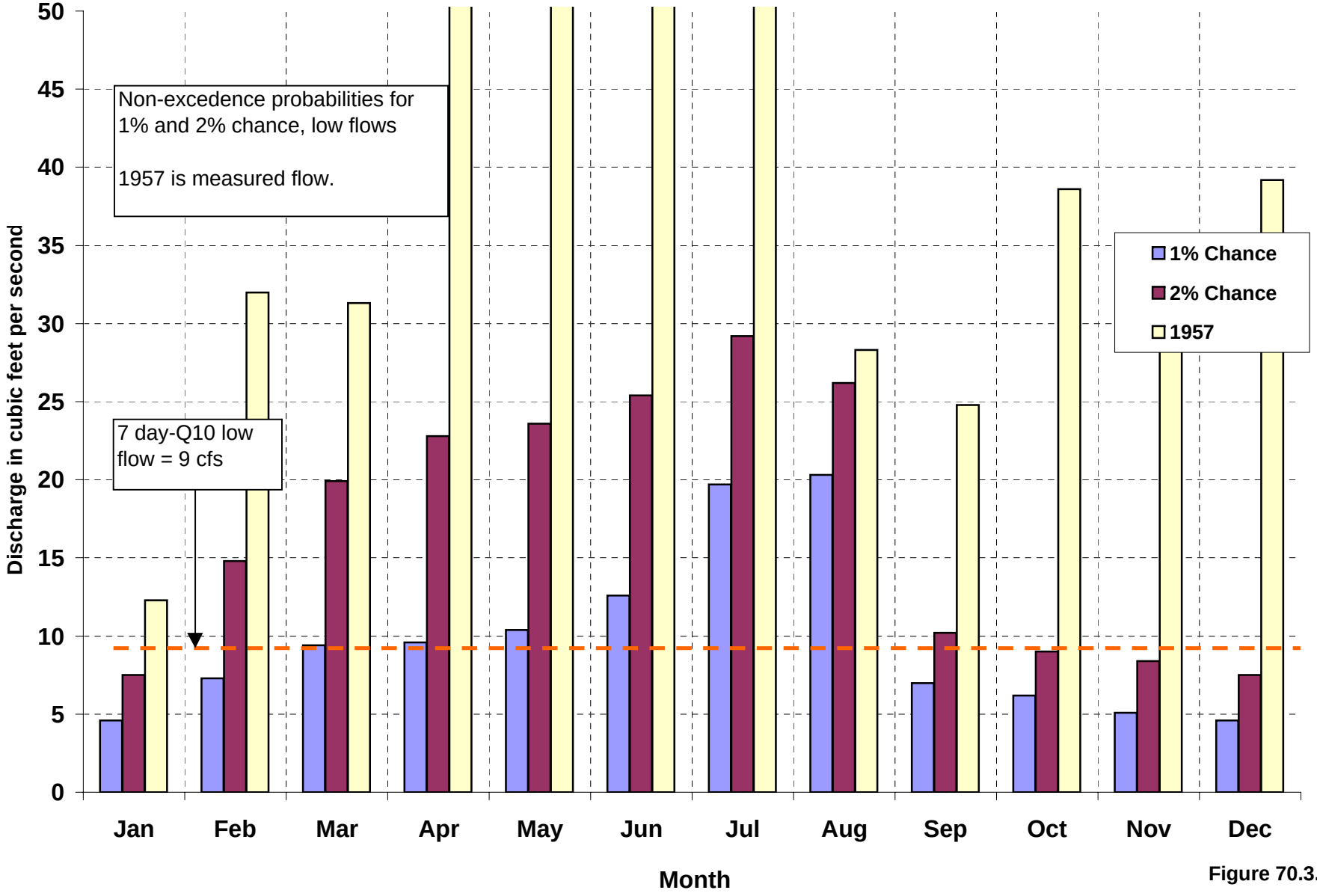


Figure 70.3.d

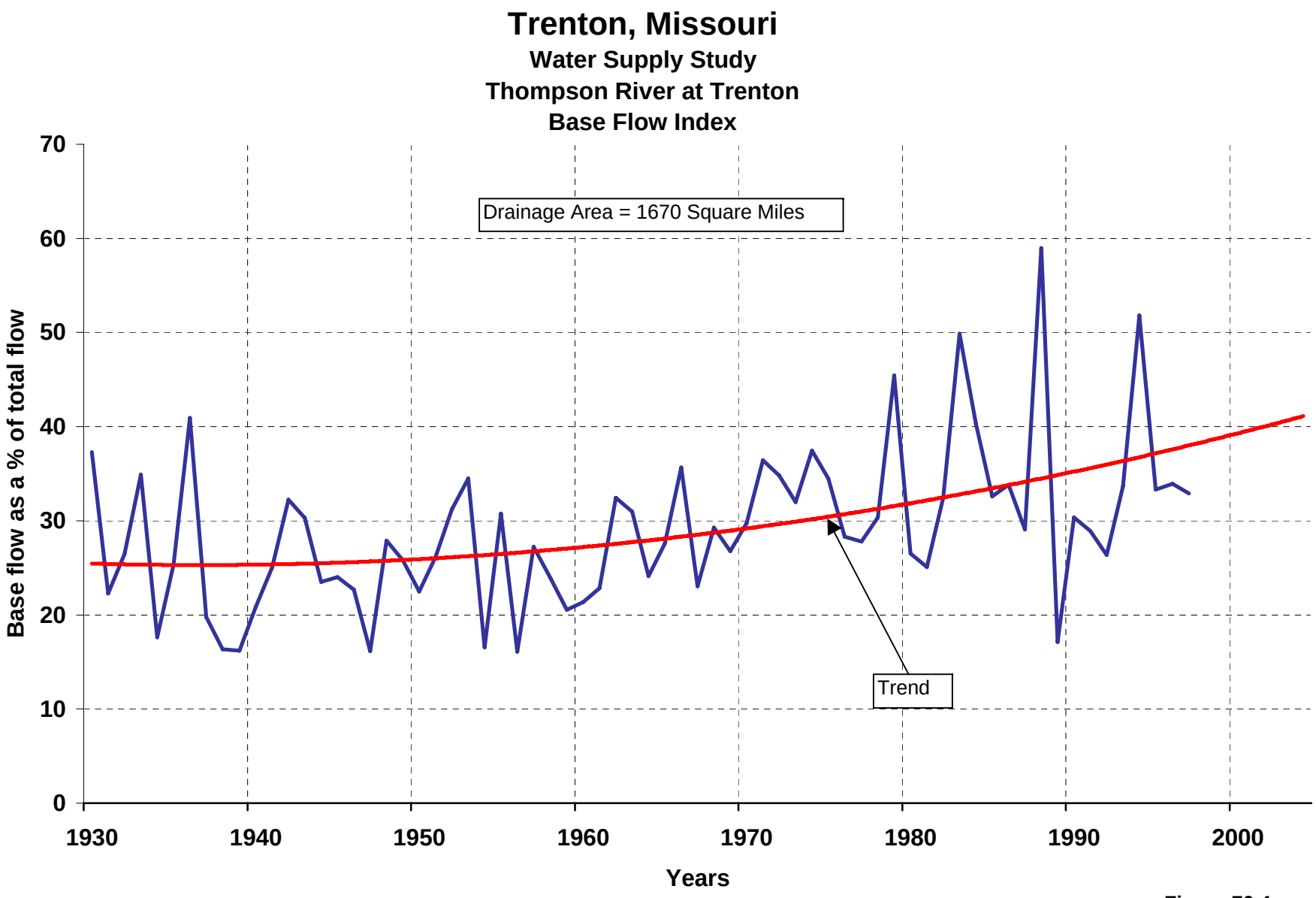

Trenton, Missouri
Water Supply Study
Thompson River at Trenton
Base Flow Index
Drainage Area = 1670 Square Miles
Trend
Base flow as a % of total flow
Years
0
10
20
30
40
50
60
70
1930
1940
1950
1960
1970
1980
1990
2000

Figure 70.4.a

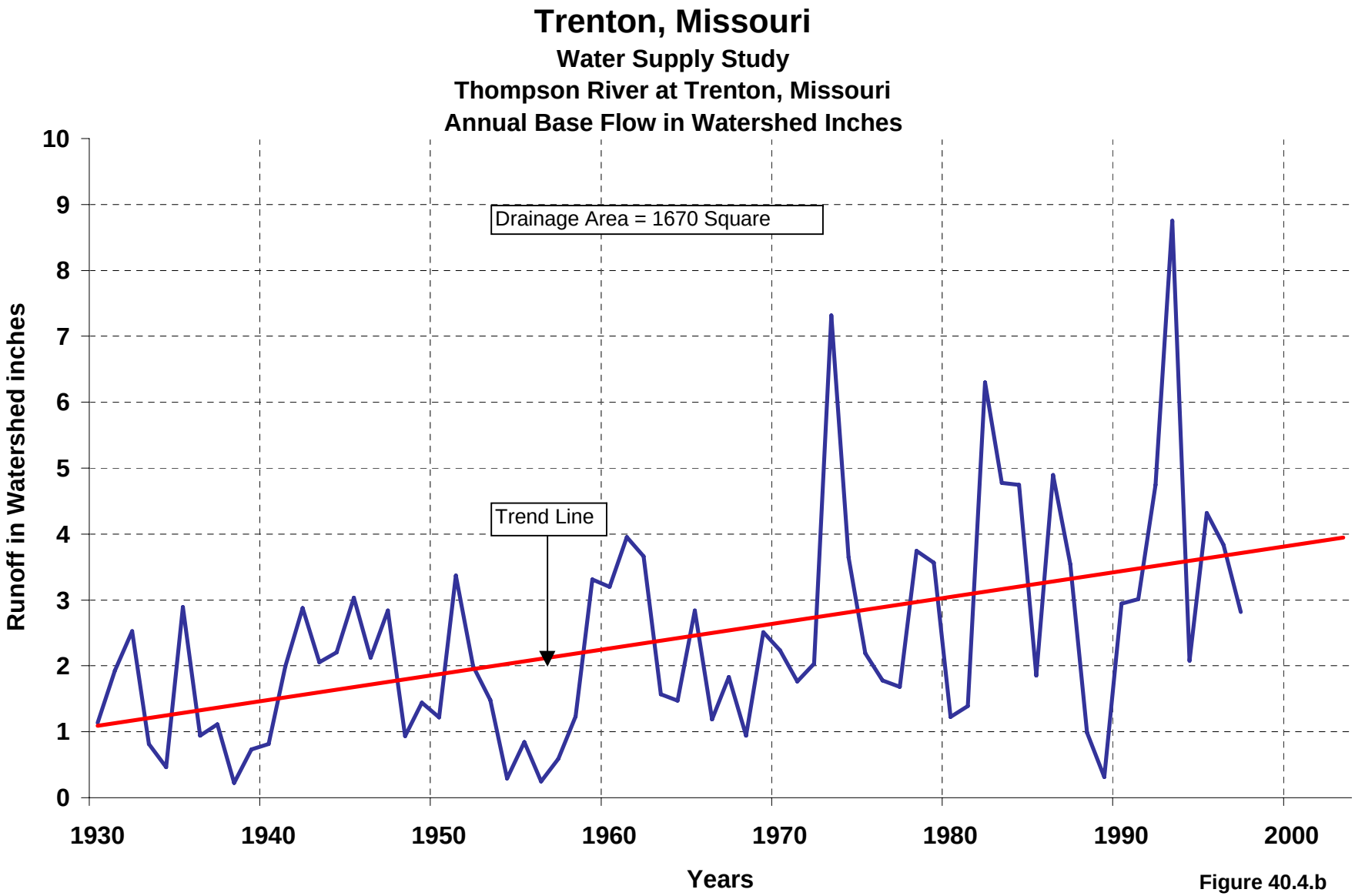

Trenton, Missouri
Water Supply Study
Thompson River at Trenton, Missouri
Annual Base Flow in Watershed Inches
Drainage Area = 1670 Square
Trend Line
Runoff in Watershed inches
Years
0
1
2
3
4
5
6
7
8
9
10
1930
1940
1950
1960
1970
1980
1990
2000

Figure 40.4.b

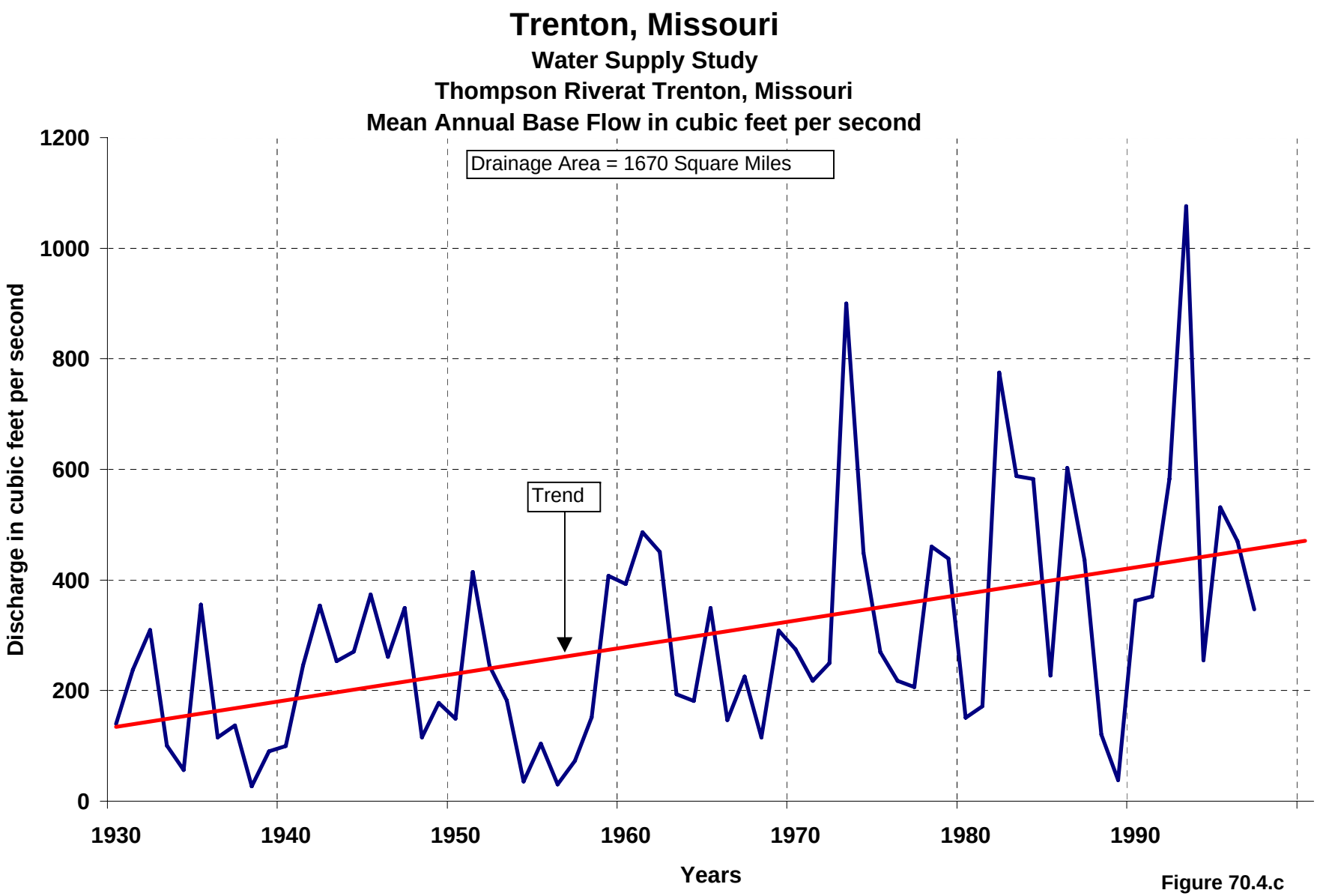

Trenton, Missouri
Water Supply Study
Thompson Riverat Trenton, Missouri
Mean Annual Base Flow in cubic feet per second
Drainage Area = 1670 Square Miles
Trend
Discharge in cubic feet per second
0
200
400
600
800
1000
1200
1930
1940
1950
1960
1970
1980
1990
Years

Figure 70.4.c

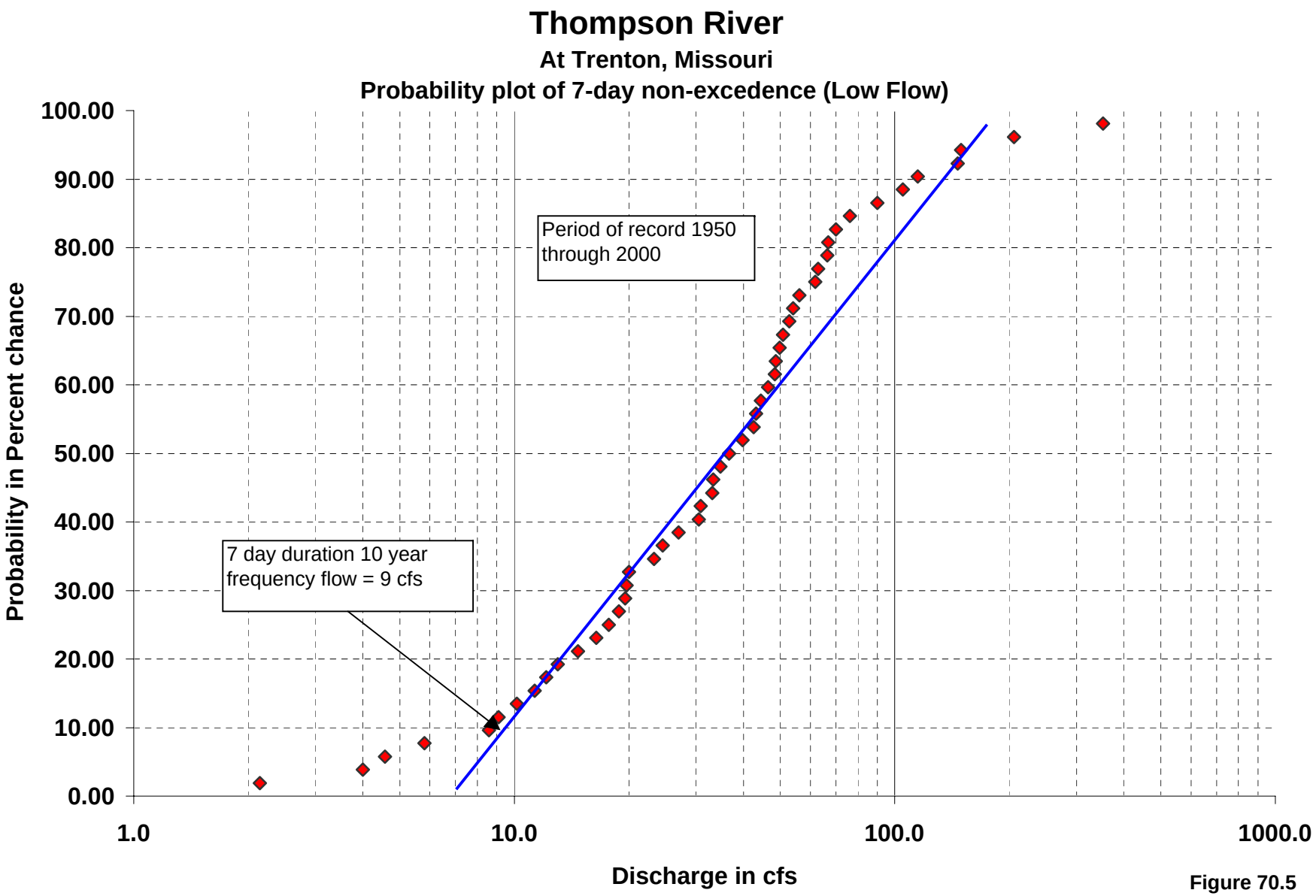

Thompson River
At Trenton, Missouri
Probability plot of 7-day non-excedence (Low Flow)
Probability in Percent chance
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.0
10.0
100.0
1000.0
Discharge in cfs
Period of record 1950 through 2000
7 day duration 10 year frequency flow = 9 cfs

Figure 70.5

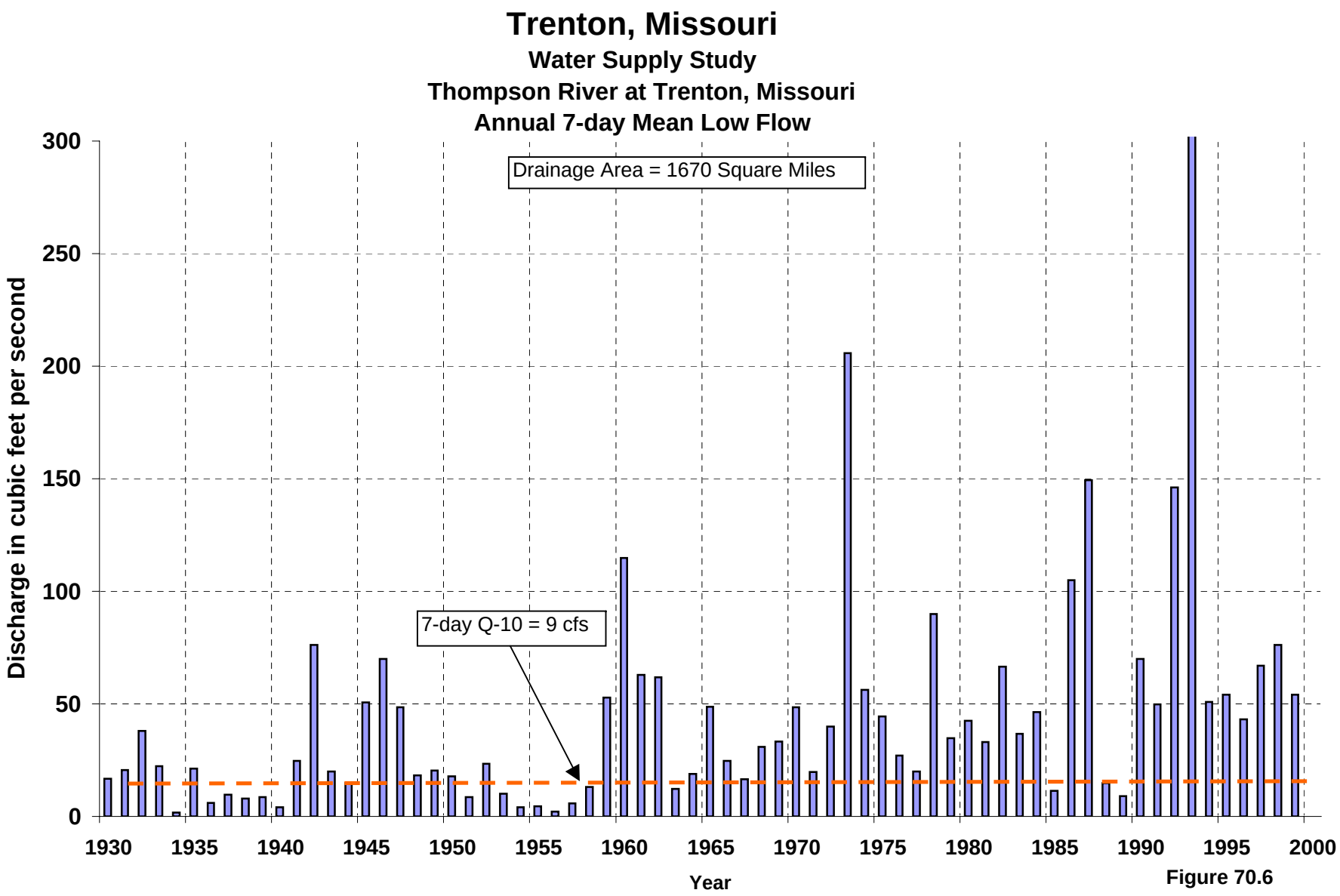

Trenton, Missouri
Water Supply Study
Thompson River at Trenton, Missouri
Annual 7-day Mean Low Flow
Drainage Area = 1670 Square Miles
7-day Q-10 = 9 cfs
Discharge in cubic feet per second
300
250
200
150
100
50
0
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

Figure 70.6

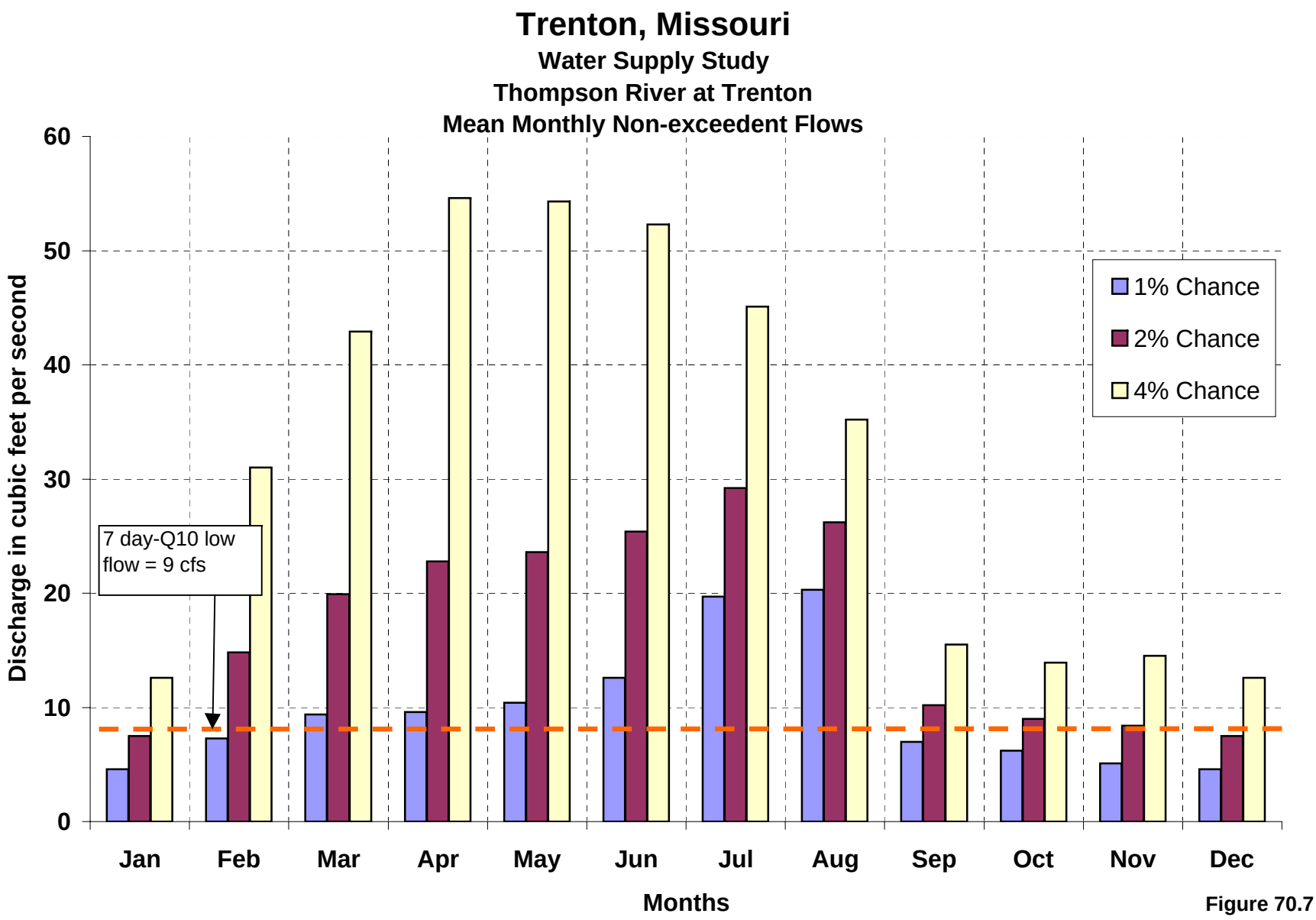

Trenton, Missouri
Water Supply Study
Thompson River at Trenton
Mean Monthly Non-exceedent Flows
Discharge in cubic feet per second
60
50
40
30
20
10
0
1% Chance
2% Chance
4% Chance
7 day-Q10 low flow = 9 cfs
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

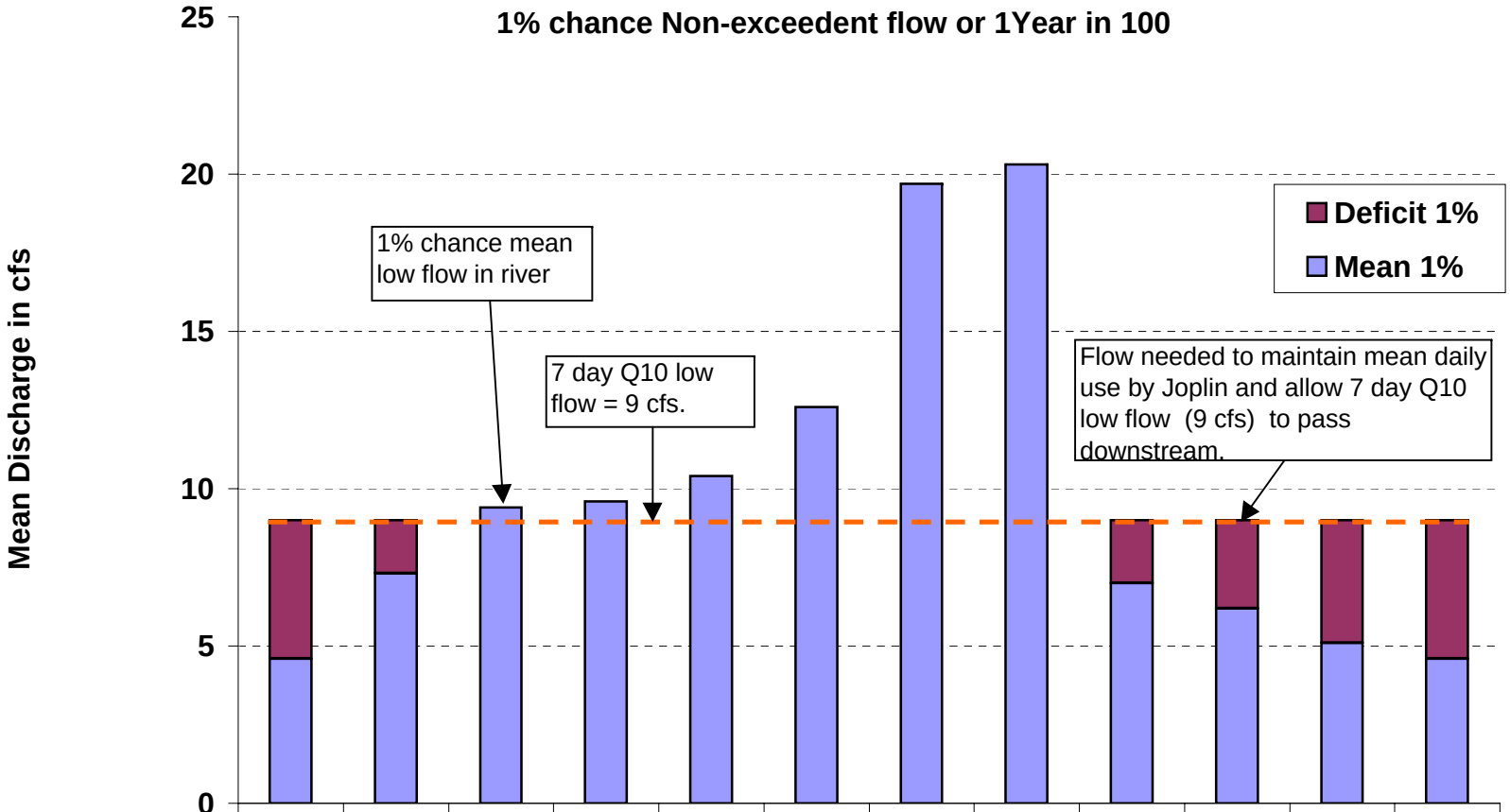
Figure 70.7

Trenton, Missouri

Water Supply Study

Thompson River at Trenton

1% chance Non-exceedent flow or 1Year in 100



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit 1%	4.4	1.7	0	0	0	0	0	0	2	2.8	3.9	4.4
Mean 1%	4.6	7.3	9.4	9.6	10.4	12.6	19.7	20.3	7	6.2	5.1	4.6

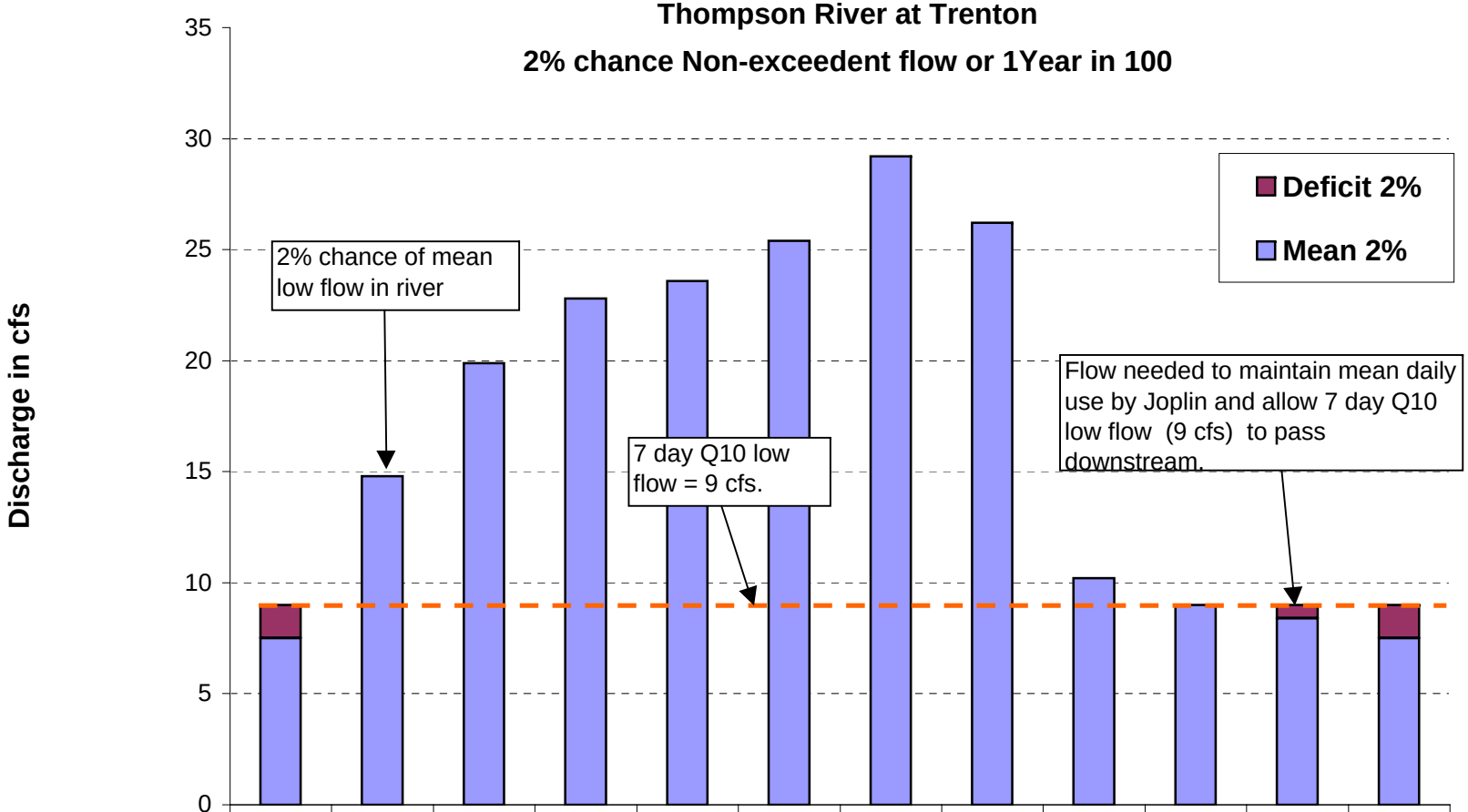
Figure 70.8.a

Trenton, Missouri

Water Supply Study

Thompson River at Trenton

2% chance Non-exceedent flow or 1Year in 100



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit 2%	1.5	0	0	0	0	0	0	0	0	0	0.6	1.5
Mean 2%	7.5	14.8	19.9	22.8	23.6	25.4	29.2	26.2	10.2	9	8.4	7.5

Month

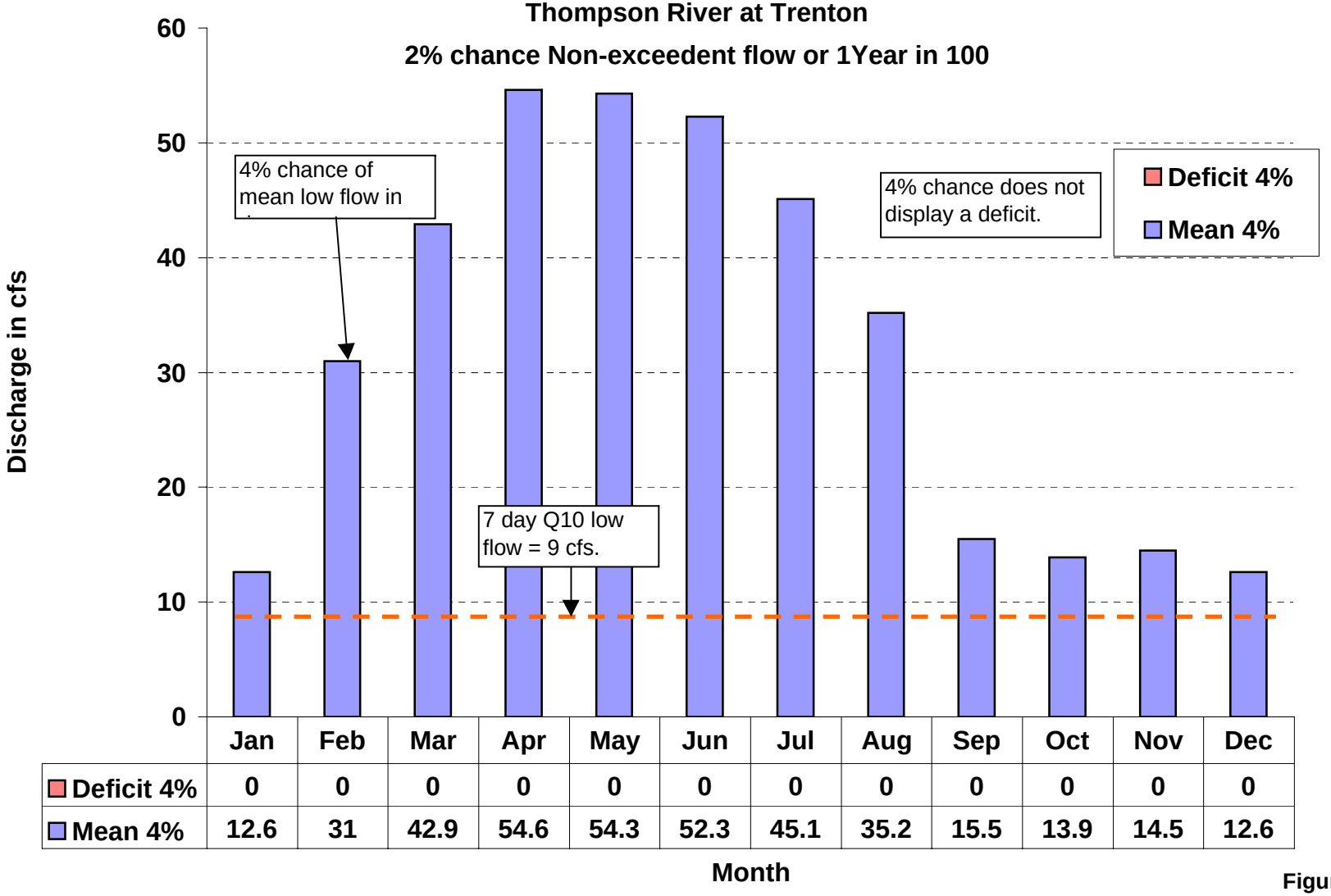
Figure 70.8.b

Trenton, Missouri

Water Supply Study

Thompson River at Trenton

2% chance Non-exceedent flow or 1Year in 100



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit 4%	0	0	0	0	0	0	0	0	0	0	0	0
Mean 4%	12.6	31	42.9	54.6	54.3	52.3	45.1	35.2	15.5	13.9	14.5	12.6

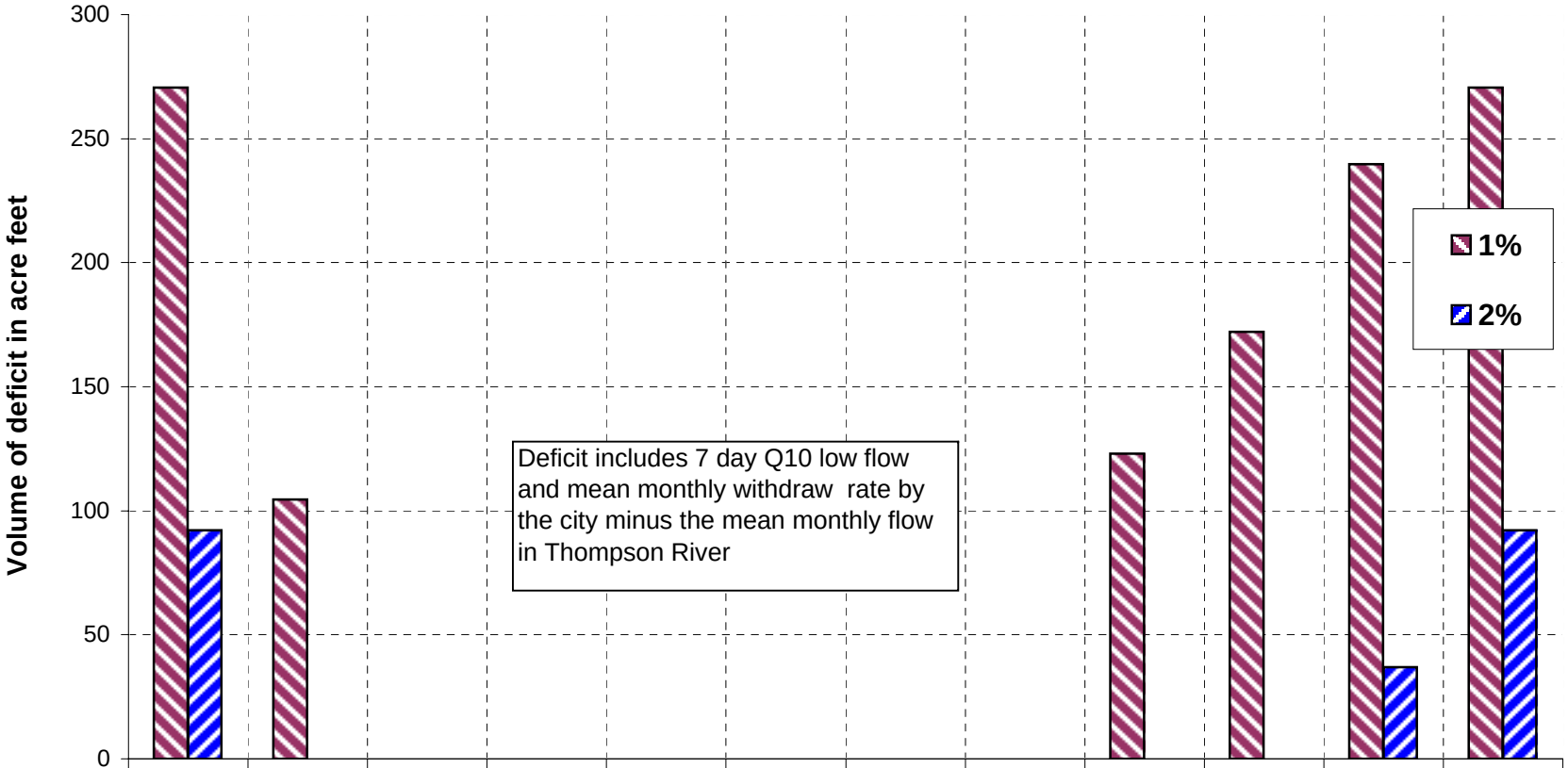
Figure 70.8.c

Trenton, Missouri

Water supply Study

Thompson River at Trenton, Missouri

Monthly Deficit in Acre Feet



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1%	271	105	0	0	0	0	0	0	123	172	240	271
2%	92	0	0	0	0	0	0	0	0	0	37	92

Month

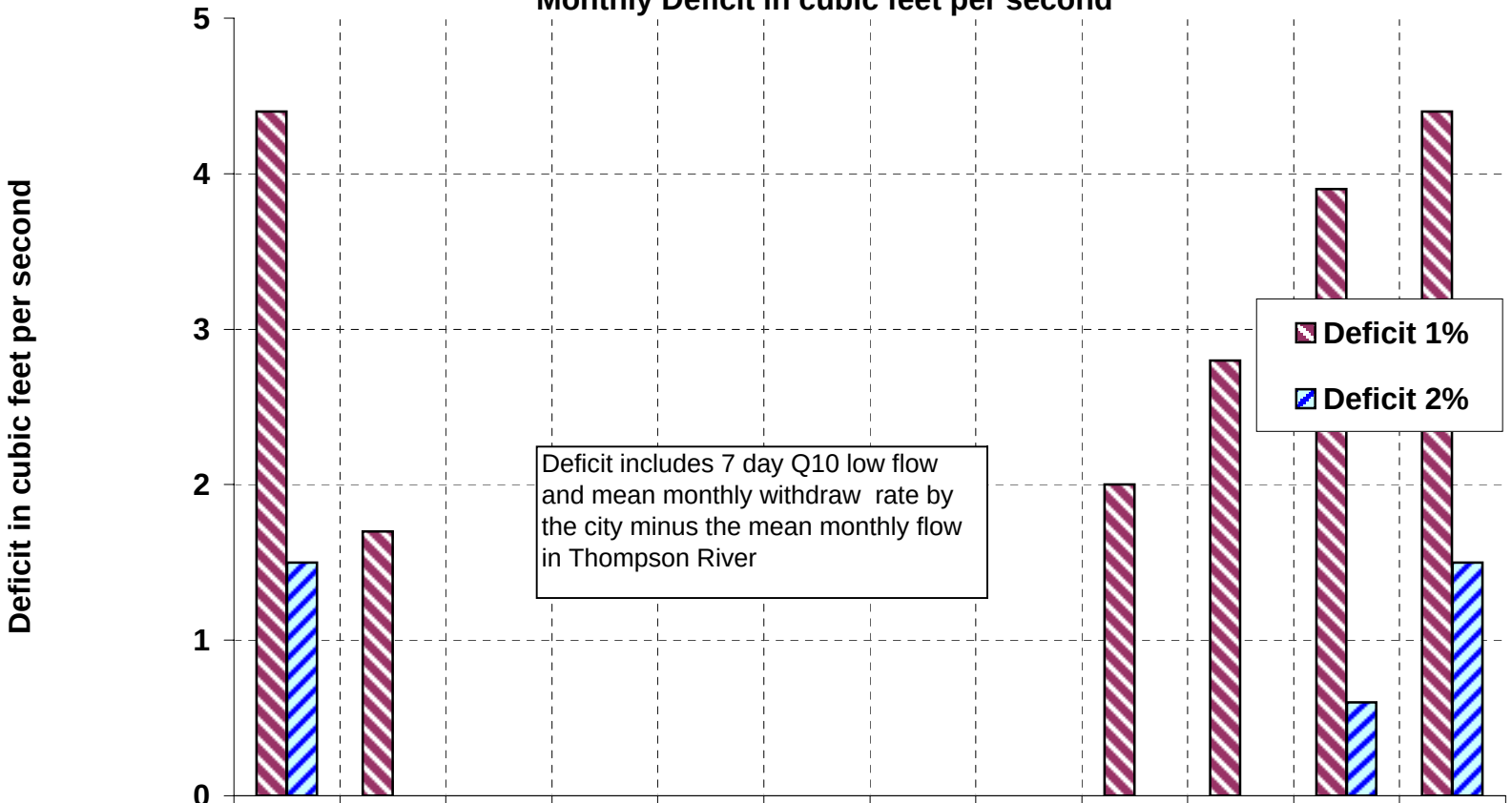
Figure 70.8.d

Trenton, Missouri

Water supply Study

Thompson River at Trenton, Missouri

Monthly Deficit in cubic feet per second



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deficit 1%	4.4	1.7	0	0	0	0	0	0	2	2.8	3.9	4.4
Deficit 2%	1.5	0	0	0	0	0	0	0	0	0	0.6	1.5

Figure 70.8.e

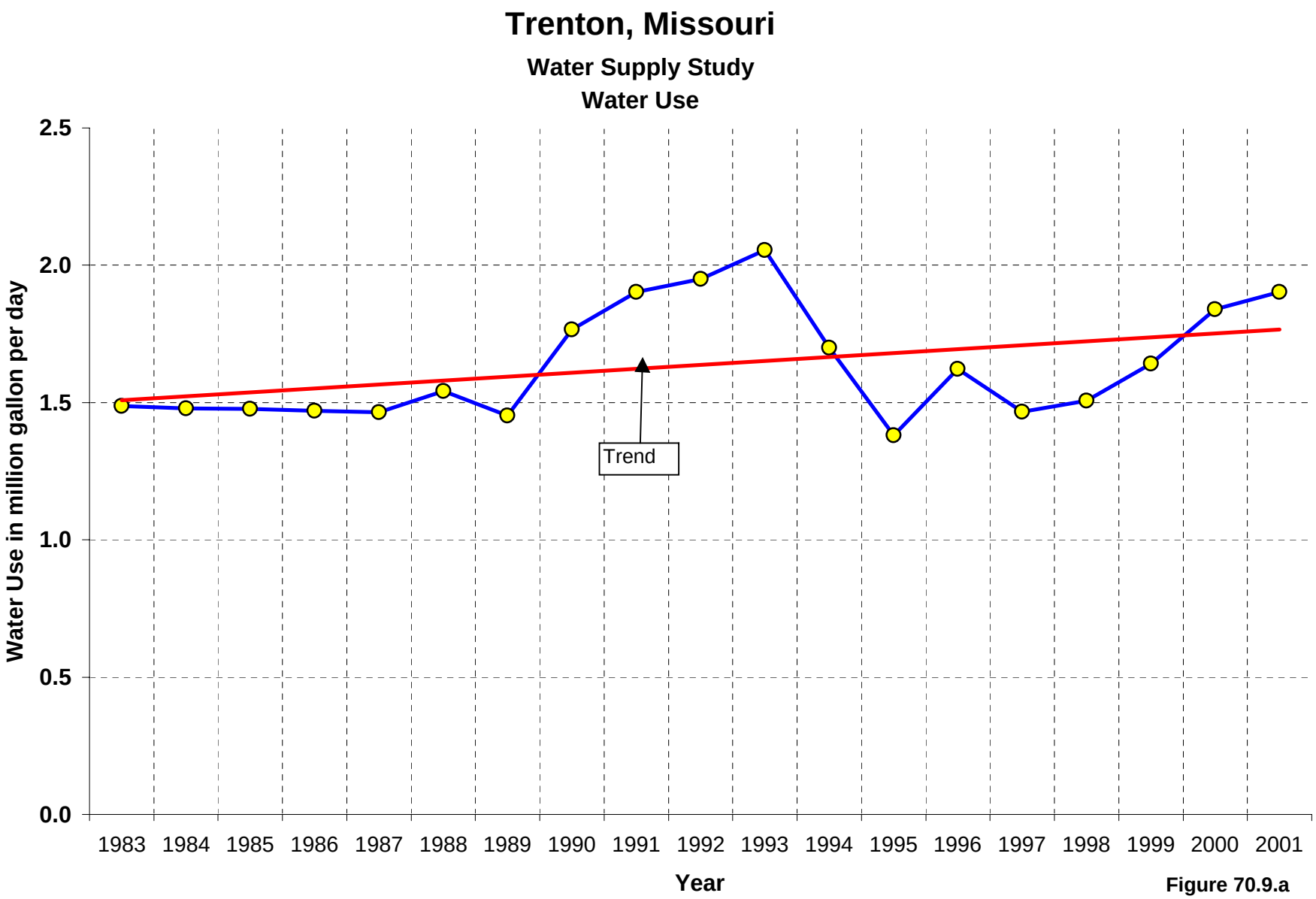

Trenton, Missouri
Water Supply Study
Water Use
Water Use in million gallon per day
2.5
2.0
1.5
1.0
0.5
0.0
Trend
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

Figure 70.9.a

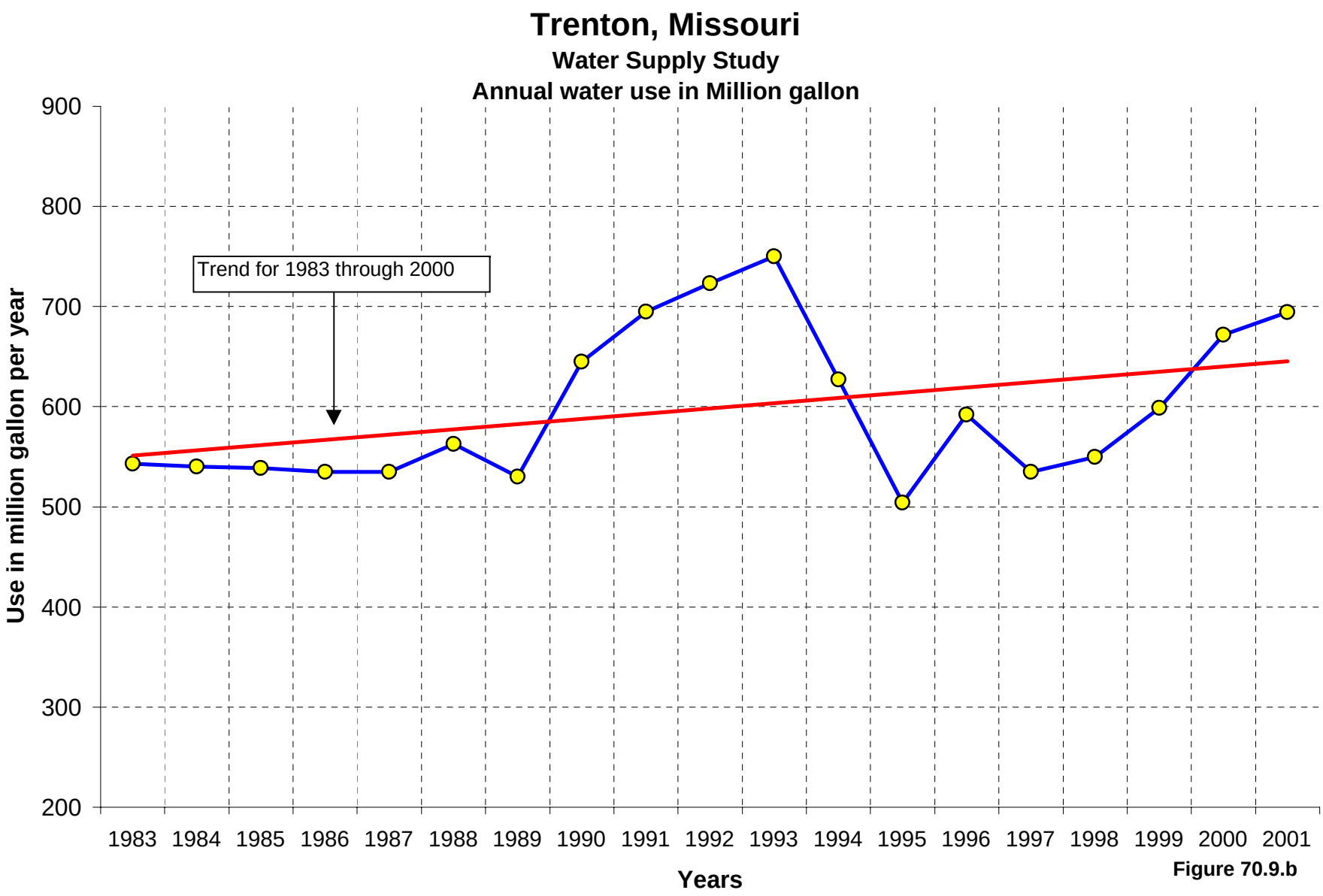

Trenton, Missouri
Water Supply Study
Annual water use in Million gallon
Trend for 1983 through 2000
Use in million gallon per year
900
800
700
600
500
400
300
200
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Years

Figure 70.9.b

Trenton Missouri

Water Supply Study

Thompson RiverAt Trenton, Missouri

Mean 7-day low flow for 1954

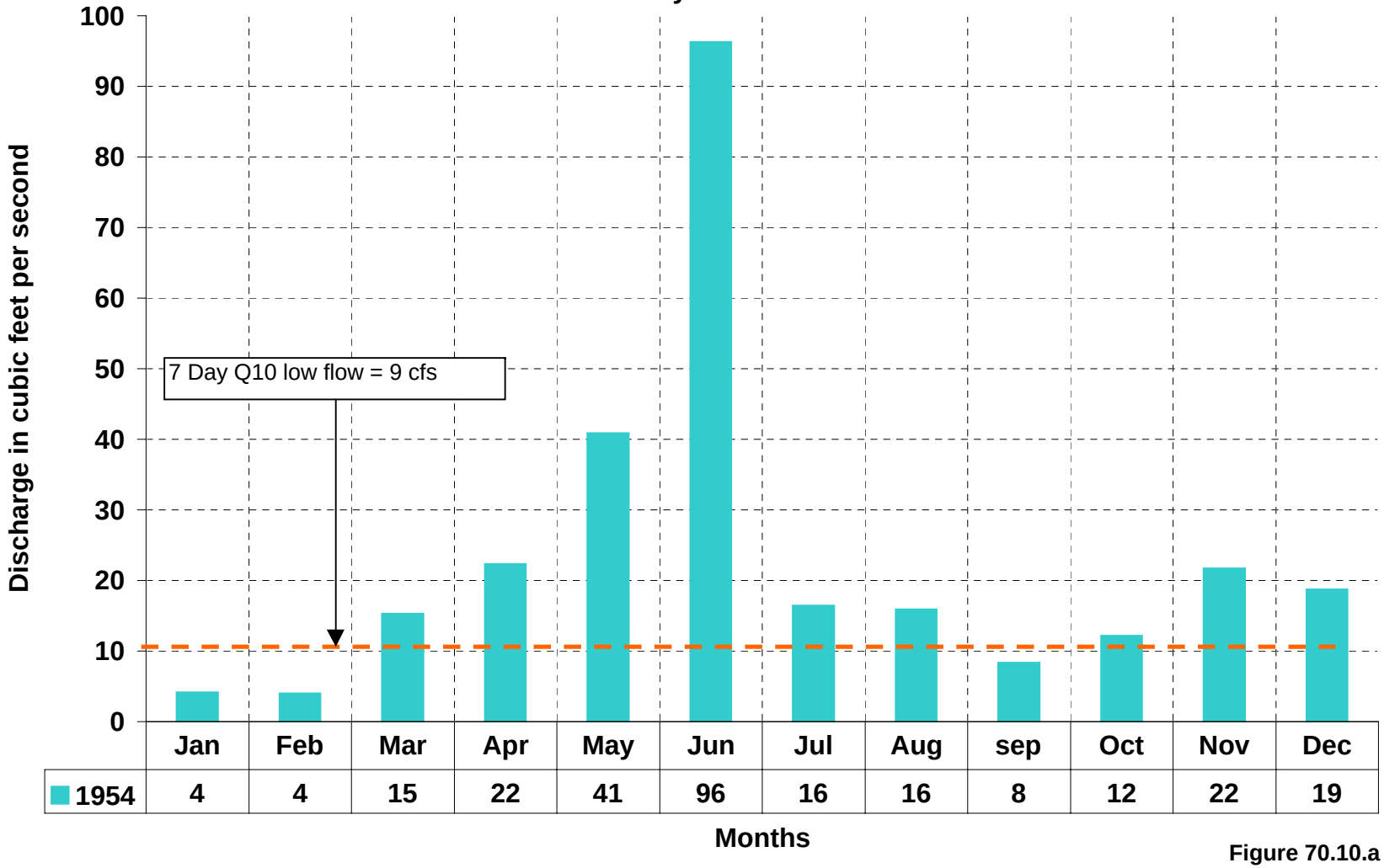


Figure 70.10.a

Trenton Missouri

Water Supply Study

Thompson RiverAt Trenton, Missouri

Mean 7-day low flow for 1955

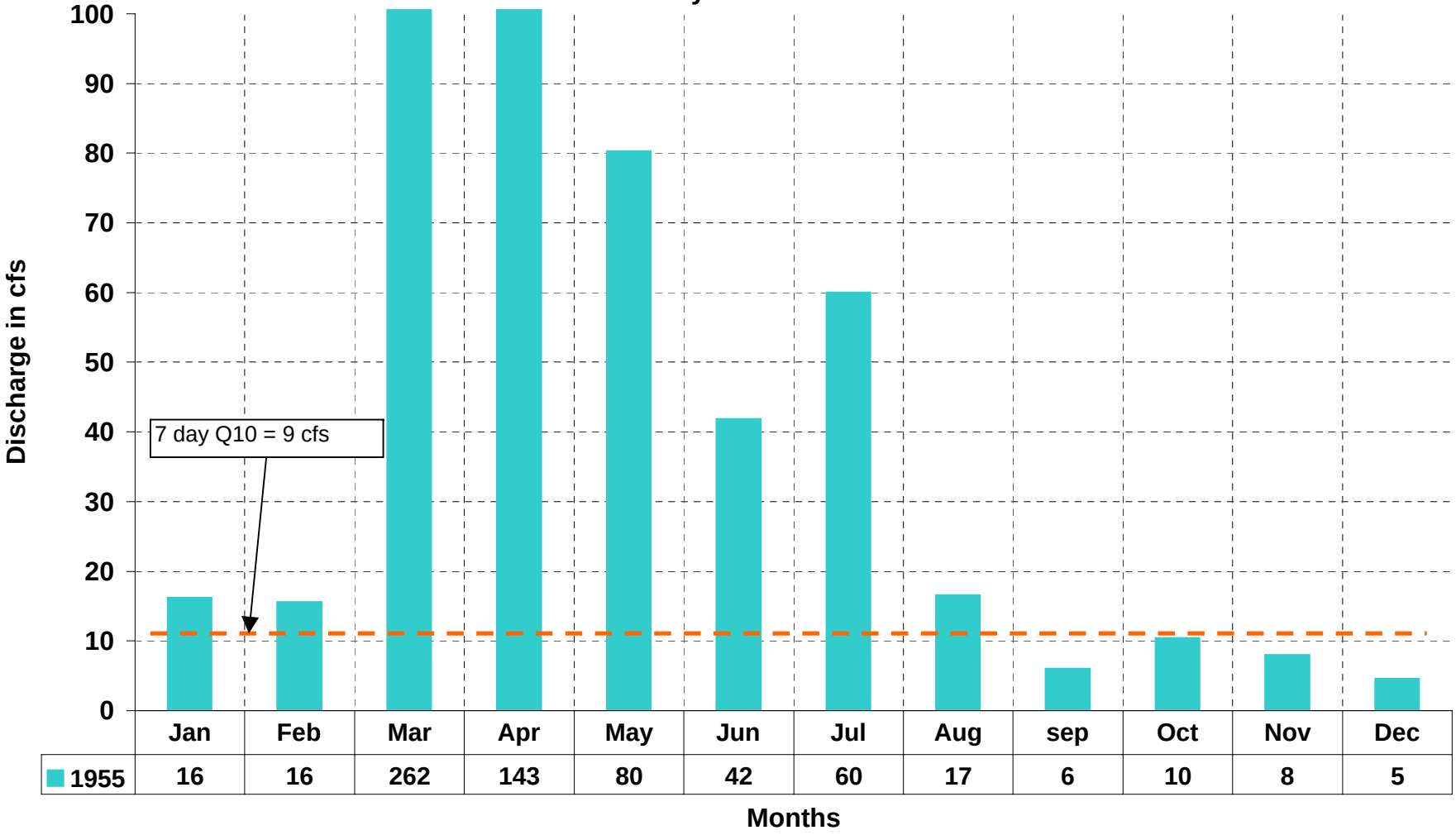


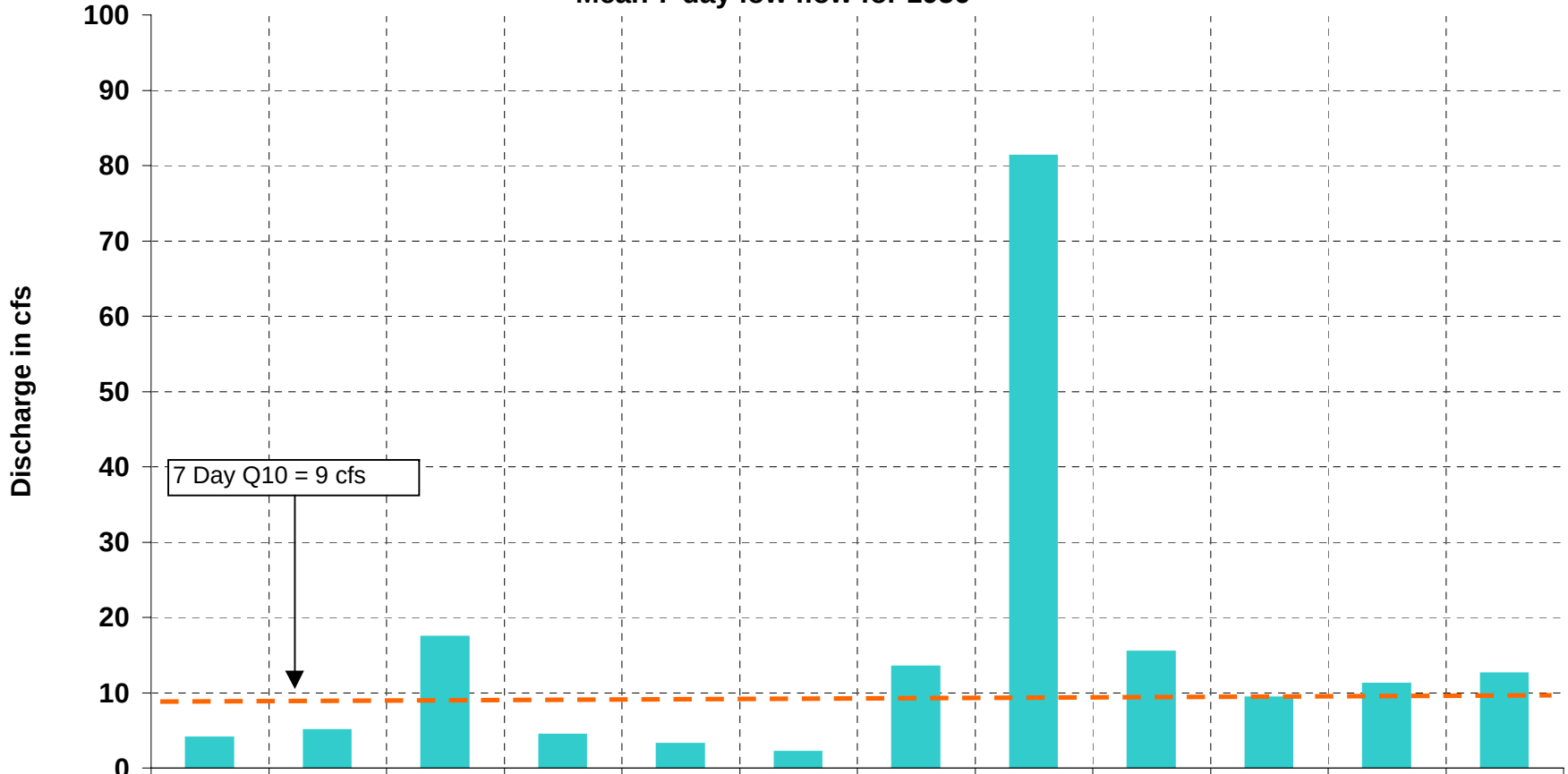
Figure 70.10.b

Trenton Missouri

Water Supply Study

Thompson RiverAt Trenton, Missouri

Mean 7-day low flow for 1956



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	sep	Oct	Nov	Dec
1956	4	5	17	4	3	2	13	81	15	9	11	13

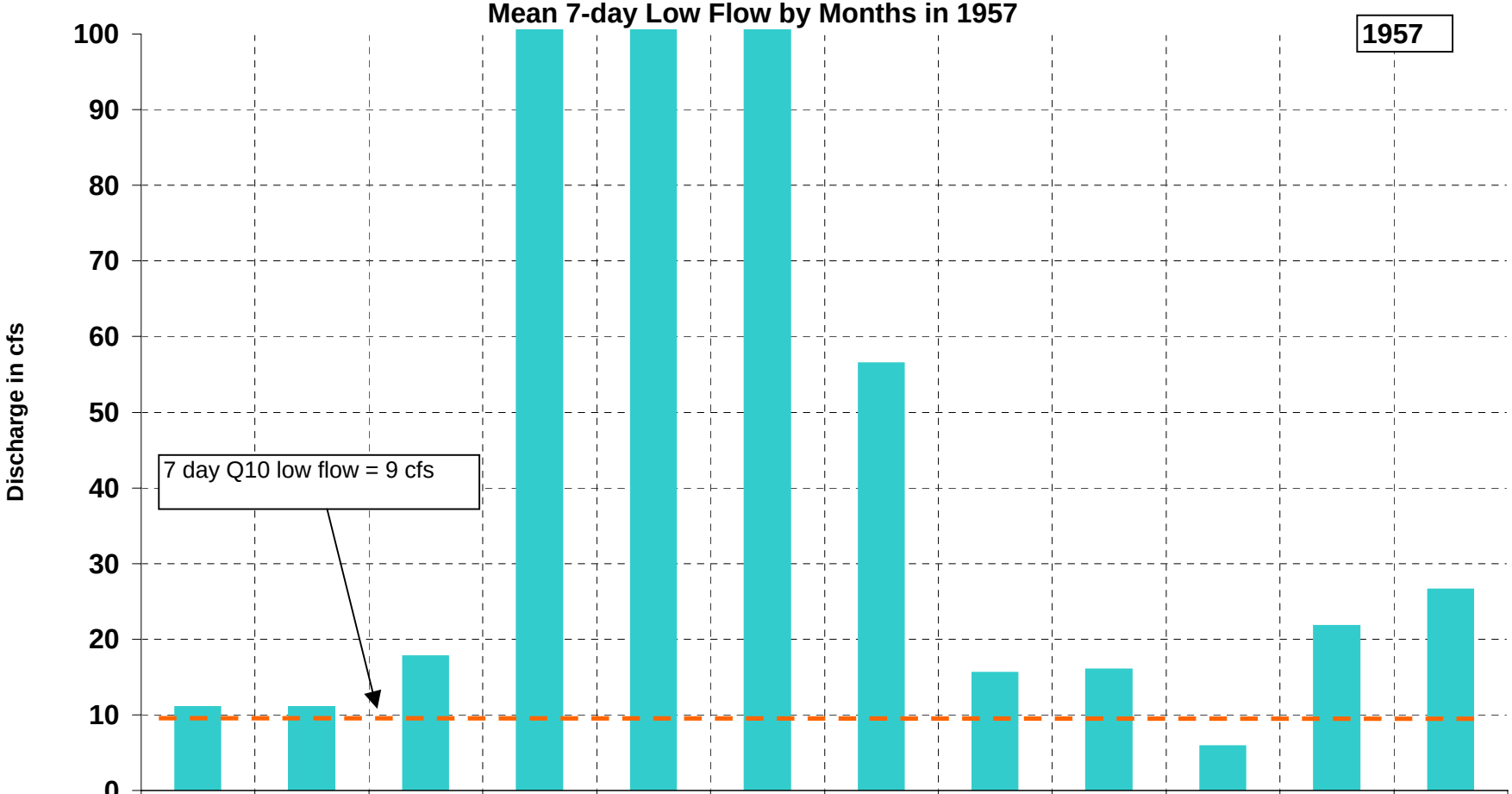
Months

Figure 70.10.c

Thompson River

At Trenton, Missouri

Mean 7-day Low Flow by Months in 1957



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	sep	Oct	Nov	Dec
1957	11	11	18	101	111	212	56	16	16	6	22	27

Months

Figure 70.10.d